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Moving America More Efficiently

Advanced Transportation Management Technologies

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16. Abstract

The Participant Notebook was developed to provide a document that contains the visual aids for the Participants as covered in the workshop of DP 105, Advanced Transportation Management Technologies. It contains the relevent information of the metropolitan intelligent transportation infrastructure elements as well as techniques/strategies and technologies of each component. The workshop is designed to provide participants with the following:

- Technology transfer on the state-of-the-practice transporttion management techniques/technologies to improve mobility and safety;
- an awareness of the significant role of these management technoloies in improving mobility and safety; and
- hands-on demonstrations on the state-of-the-practice hardware and software in transportation management technologies

Participants of the workshop include:

- Decision makers from State and local Departments of Transportation (DOTs), Departments of Public Works (DPWs), and Metropolitan Planning Organizations (MPOs)
- State and local highway managers, planning policy makers, and administrators
- Highway and traffic engineers and engineering technicians

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Freeway Management System
Overview

- Freeway Management System is a component of a comprehensive Transportation Management System as described under the metropolitan intelligent transportation infrastructure.

Freeway Management System
Overview

- Strategies
- System Components
- Technologies

- FMS utilizes various strategies and technologies to enable the freeway traffic to move effectively.

Freeway Management System
Strategies and Techniques

- Freeway Management Strategies may be categorized in to six (6) basic techniques.

- Incident management strategies may be based on series of subsystems and procedures that incorporate detection, confirmation, and response. Incident management is discussed in detail later in our presentation.

Freeway Management System
Strategies and Techniques

- Ramp Control
- Mainline Control
- Dynamic Roadway Control
- Priority Control for HOV
- Traveler Information/Route Guidance
- Incident Management

Freeway Management System
Tools and Technologies

- Existing tools available for implementation and operation of a Freeway Management System will utilize one or more of these technologies to monitor and operate the system.

Freeway Management System
Tools and Technologies

- Detection
- Traffic Surveillance
- Dynamic Message Signs
- Vehicle/User Devices
- Highway Advisory Radio

Freeway Management System
Communication

- Communication is the key to the successful implementation and operation of a Freeway Management System.

Freeway Management System
Communication

- Transmission
- Architecture
- Guidelines and Standards
- Selection Techniques
- NTCIP

- To design a comprehensive system, four questions need to be addressed for each component and the overall system:
  1. What are the system requirements?
  2. What are the applicable communication technologies?
  3. How do you select the appropriate technology?
  4. What impacts will the NTCIP have on your selection process?

Detection
Techniques and Strategies

- Detection provides the TMC's with real-time traffic and weather information through electronic devices.

- Detection can be performed using various devices, automatically or in conjunction with human interaction.

Detection
Techniques/Strategies

- Vehicle Detection
- Weather and Environmental Detection
- Over Height Vehicle Detection
- Call Boxes
- CB Monitoring
- Closed Circuit TV

- Weather and Environmental Detection:
  - Surfaces Sensors
    - Pavement Temp-Detection of Ice, Frost, Water Snow
  - Atmospheric Sensors
    - Air Temp, Dew Point, Relative Humidity, Precipitation, Wind Direction, Wind Speed
  - Remote and Central Processing Units to collect, transmit, and process the data and allow for communication between various devices.

- Call Boxes: motorist aid and incident reporting – Now used for acquisition and transmission of traffic, weather and environmental data.

- CB Monitoring: Channel 9 official emergency channel by FCC in 1970.

- Over height vehicle detection uses infrared light to detect over height vehicles and prevent damage to vehicle and/or highway structure.

- Closed Circuit TV: can be used to monitor operation and detect incidents within a specified range.

Vehicle Detection
Technologies

Vehicle Detection
Technologies

- Inductive Loop
- Magnetometer
- Radar/Microwave
- Ultrasonic
- Infrared
- Video Imagery

- Inductive Loop – most widely used; costly to maintain; can provide volume speed, occupancy, presence, headway, and classification.

- Magnetometer – limited use on bridge decks or deteriorated pavement.

- Radar/Microwave – provides volume, speed, occupancy, presence; vehicle mix may affect results; susceptible to interference from other devices operating at the same frequency.

- Ultrasonic – specific detection zone; detects sounds; overhead mounted - limited success with side mounted-emulated loop output, requires no modification to system hardware; provides volume, speed, occupancy, presence and classification; environmentally susceptible to high wind, heavy snow fall and rain.

- Infrared: Active and Passive
  - Active – presence or pulse - break/interrupt the signal.
  - Passive – Measure amount that is emitted by the object

  Both can provide volume, speed, occupancy, presence, and classification. Both are susceptible to background radiation due to rain and clouds.

- Video Image Processing – cameras provide images used by video processors to emulate traffic data. "Pseudo detector" locations are not fixed and may be moved if so desired; can provide volume, occupancy, presence, speed, and classification.

Traffic Surveillance

- Accumulate accurate and reliable traffic information
- Identify and verify recurring and non-recurring congestion
- Identify severity of problem in the monitored corridors

Traffic Surveillance

- Accumulate data
- Monitor traffic
- Identify and verify incidents
- Assess severity
- Assess and evaluate response

- Identify incidents and required response
- Evaluate effectiveness of response plans. (i.e. diversion strategies, information dissemination, and alternate routes performance)
- Evaluate effectiveness of operational improvements.

Dynamic Message Signs
Overview

- Dynamic Message Signs are the most widely used technology for conveying information to motorists.
- They are a part of every deployed Freeway Management Systems to date.

Dynamic Message Signs

- Warning
- Regulation
- Routing
- Management

Dynamic Message Signs

Dynamic Message Signs

- Recurring congestion
- Non-recurring congestion
- Special events
- Environmental and weather

- Three types of real-time messages:
  - Advisory
  - Guidance
  - Advance
- Advisory messages display real-time information about the status of freeway and advise motorist as to best course of action.
- Guidance messages are used for informing motorist about available alternate routes during incident management and traffic diversion.
- Advance messages are used to alert and prepare motorist of upcoming advisories.

Dynamic Message Signs

Dynamic Message Signs
(Continued)

- Route diversion
- Highway priority and HOV
- Construction activities
- Operational characteristics

Dynamic Message Signs
Technologies

Dynamic Message Signs Technologies
♦ Rotating Drums ♦ Reflective Disks ♦ Bulb Matrix ♦ Fiber Optic ♦ Blank-out ♦ Hybrid ♦ Light Emitting Diode (LED)

- Rotating Drums are the oldest DMS type signs and can only display limited number of messages.
- Reflective Disks display messages by reflecting external sources of light.
- Bulb Matrix uses incandescent light bulbs as pixels to form characters or graphics.
- LED signs use clusters of LED's to form pixels and display messages when illuminated.

Ramp Control

- Ramp closure is the most restrictive form of ramp control and should only be used where safety maybe compromised or on sections of freeway where operation levels are at capacity or beyond.

Ramp Control

- Ramp Closure
- Ramp Metering

- Ramp control must consider operational issues such as:
  - Effects on adjacent surface streets
  - Availability of alternate access and alternate routes

  and institutional issues such as:
  - Political support
  - Public support

Ramp Metering

Ramp Metering

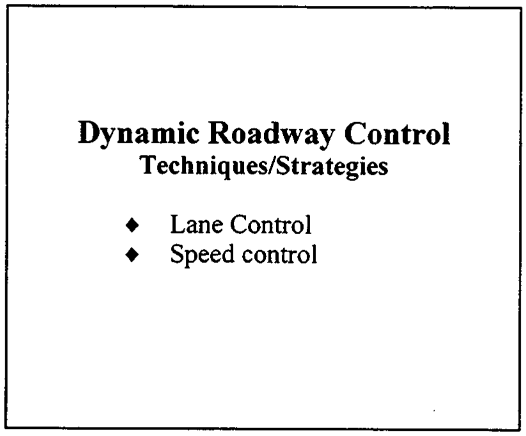
- Primary benefits
- Primary concerns

- Benefits:
  - Congestion Reduction – demand must be kept less than capacity.
  - Safety – smoother ramp merging operation by elimination of platoon merging.
- Concerns:
  - Queue lengths which back up on to the surface street.
  - Potential diversion of freeway trips to adjacent surface streets.
  - Potential for increased violation and disregard for regulatory traffic control.
  - Public perception - long delays on entry ramps although the result may be shorter overall trip-time.

Dynamic Roadway Control
Techniques and Strategies

- Lane Control – used to change the directional capacity of a freeway in order to accommodate peak directional traffic demands.

- Speed Control – to reduce speeds to a level that corresponds to maximum volume.
  Also used during hazardous driving conditions such as fog, rain, or snow.

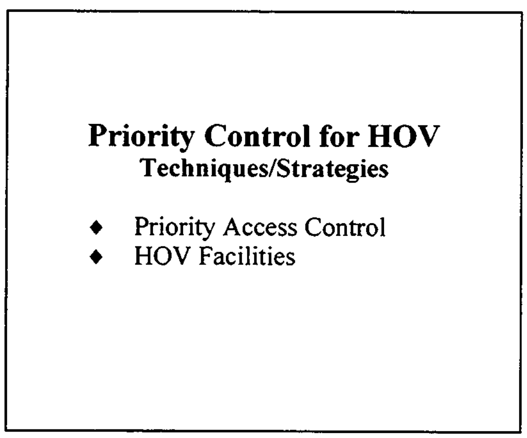


Priority Control for HOV
Techniques/Strategies

- Priority Access Control bypass lanes on ramps or ramp meters.

- Exclusive ramp for HOV.

- HOV facilities are exclusive facilities that are used primarily by high occupancy vehicles and motorcycles.



Priority Control for HOV

Technologies

- Separate right-of-way – often constructed in the median. It can effectively be used as a reversible facility based on time of day or traffic conditions.
- Concrete barriers or striping may be used to delineate a buffer zone between SOV and HOV lanes.
- Contraflow lanes require an active device such as moveable barriers, barrels or plastic posts to separate contra flow HOV traffic from the oncoming traffic.

Priority Control for HOV
Technologies

- Separate Right-of-Way
- Buffer and/or Concrete Barrier
- Paint Striping of Buffer for Delineation (Concurrent Flow Lane)
- Plastic Posts or Moveable Barriers for Delineation (Contraflow Lane)

Priority Control for HOV

Technologies (Continued)

- HOV bypass lanes on ramp provide for uninterrupted movement of HOV vehicles. Examples of HOV bypass lanes are seen throughout California and other jurisdictions that utilize ramp metering. Bypass lanes may require widening of ramps.

Priority Control for HOV
Technologies

- Bypass Lanes at a Ramp
- Exclusive Ramps
- Changeable Message Signs
- Closed Circuit TV

- Dynamic message signs are used to provide the motorist with information about HOV facilities.
  - Type (2 PPV, 3 PPV, Buses Only, Motorcycles)
  - Hours of operation
  - Roadway status
- Closed Circuit TVs are used for surveillance of traffic operations as well as enforcement requirements.

Highway Advisory Radio
Techniques/Strategies

- Whip or Vertical Antenna Systems (VAS) – Individual or series of antennas electronically connected together to transmit information. VAS has a circular area of transmission.

> **Highway Advisory Radio**
> **Techniques/Strategies**
>
> - Vertical "Whip" antenna systems
> - Inductor cable antenna systems

- Inductor Cable Antenna System – These systems use a cable installed either in the pavement or adjacent to the roadway.

Transportation Management During Reconstruction

- Trailer mounted DMS provide the flexibility to display a variety of messages that best suit the needs of the agency.

- Arrow displays are used for stationary or moving lane closures.

> **Transportation Management**
> **During Reconstruction**
>
> - Trailer mounted DMS
> - Arrow displays
> - Portable channelization
> - Temporary Traffic Signals
> - Portable HAR
> - Temporary VID

- The design and functionality of temporary traffic signals is not much different than the permanent signals except for the use of such techniques as alternate power sources and portable loops or VID's.

- Portable HAR requires alternate power sources.

In Vehicle Navigation Devices

- Automated vehicle location technology provides vehicle positioning in real time.

- In-vehicle display is used to display the area map showing the vehicle position.

- Map information may be store on CD ROM and used to by the processor to display information on the In-vehicle display.

In-Vehicle Navigation Devices

- AVL
- In-Vehicle Display
- Map Information
- Route Information

- Route information may be provided by the TMC or private services. The information is real time information about the status of the transportation system through wireless, area-wide communication.

Communications
Overview

Communications
Overview

- Architecture is important
- 2/3rds of most projects devoted to communications
- Traffic system defines communications requirements
- Media selection comes last, not first

- Architecture is important. Communications architectures that do not provide throughput reliability for the requirements of the system will make an unreliable system. But throughput reliability can also be too high, making the communications network too expensive. Because the communications system will typically take two-thirds of the project cost, mistakes made here can be costly.

- The first step defines the traffic needs, followed by the architecture of the traffic system. Then communications architectures can be designed efficiently. Finally, media that fit in with the communications architecture will provide the most appropriate service for the least cost.

Communication
Requirements

- Requirements for communications are based on the system architecture. Once the system architecture is known, the designer must catalog data and video signals that need to traverse the communications network. The designer must also understand the proposed and potential diversity of devices within the system, and deploy appropriate standards to accommodate such diversity.

Communications
Requirements

- Data
- Video
- System Reliability vs. Communications Reliability
- Standards

Data Transmission
Deterministic Architectures

> **Data Transmission**
> **Deterministic Architectures**
>
> - Advantages
>   - Appropriate for centralized systems
>   - Uses telephone technology
> - Disadvantages
>   - Limited channel sizes
>   - Inefficient
>   - Potentially expensive

- Deterministic architectures provide a guaranteed, fixed capacity to each remote device. Protocols impose a strict discipline on messages such that they are entirely predictable. This approach is highly suited to centralized architectures that require real-time communications for system-critical functions. Because of its emphasis on individual fixed channels, the deterministic approach is very similar to telephone systems, and can easily be implemented with telephone-industry multiplexing schemes.

- The communications network must guarantee a predictable service to each device. Therefore, any random variation in message size is prohibited, and the network is constrained to always deliver all messages predictably. Each channel must therefore be limited in size to ensure that all channels will be a predictable size.

- The deterministic approach usually uses circuit switching, which, though common in the telephone industry, is hardware-intensive and therefore potentially expensive and difficult to maintain.

Deterministic Networks
Examples

Deterministic Networks
Examples

- Electrical Digital Hierarchy
- TransGuide's SONET, San Antonio

- The Electrical Digital Hierarchy defines the standards used by the telephone industry for combining, or multiplexing, large numbers of private channels onto high-capacity links. The hierarchy is divided into three parts. The lowest level includes basic serial services, such as the serial communications on desktop computers or common traffic signal systems. The middle level defines the T-1 standards for multiplexing digital voice channels onto conditioned twisted-pair copper wire. The highest level defines how multiple T-1's can be combined into fiber-optic networks.

- TransGuide's SONET provides an example of an entire system managed through common telephone switching equipment. This example also will demonstrate later how the same technology can be used to control video signals.

Data Transmission
Non-Deterministic Architectures

- Non-Deterministic architectures use a single, shared large channel. All devices hear all messages, and only respond to those messages with the appropriate address. Protocol must provide reliability assurances such as guaranteed delivery, sequential ordering, error correction, and collision recovery.

> **Data Transmission**
> **Non-Deterministic Architectures**
>
> - Advantages
>   - Appropriate for Distributed Systems
>   - Uses computer-industry technology
>   - Allows flexible use of capacity
>   - Potentially cost-effective
> - Disadvantages
>   - Doesn't guarantee timely message delivery

- By not dividing the trunklines into small, fixed channels, this approach allows a single device to use the whole large capacity when needed. This approach is especially useful where communications are bursty, such as traffic signals, where database downloads are far more intensive than routine monitoring.

- Non-deterministic systems usually use packet-switched communications media, but can be run through multiplexed circuit-switched systems as well.

- These systems cannot be used in traffic systems that require system-critical real-time message delivery.

Non-Deterministic Networks
Examples

> **Non-Deterministic Networks**
> **Examples**
>
> - The Internet
> - NTCIP
> - The Las Vegas Area Computer Traffic System

- The Internet provides the most understandable contact with non-deterministic networks. When the network is heavily loaded, information moves slowly. When the network is not congested, messages move more quickly. The speed at which messages move depends on the demand on that portion of the network at that instant. That demand is controlled by the random actions of thousands of users, and is therefore a mostly random process. When moving large files, however, other messages can be slowed down to make room for the bigger need. This allows the available capacity to be efficiently used.

- Ethernet, which is a standard for local area network communications, provides another example of non-deterministic communications. The operation is similar to the Internet, but most people never experience the kinds of delays that illustrate the point of non-deterministic systems.

- In the traffic industry, most closed-loop traffic signal systems use non-deterministic communications schemes. In fact, the National Transportation Communications for ITS Protocol uses non-deterministic techniques to ensure effective message delivery over shared channels.

- An example of a system designed around non-determinism is the Las Vegas Area Computer Traffic System. LVACTS provides high-bandwidth paths to hub computers, and low-bandwidth paths to groups of field devices. Rather than multiplexing an individual channel to each field device, all devices on their physical branch hear all messages. The use of the channel is switched, therefore, by the information in the packet, which is the definition of packet-switching.

Video Transmission
Overview

> **Video Transmission**
> **Overview**
>
> - Analog
>   - 4.5 MHz for image
>   - 1.5 MHz for audio
>   - 30 frames per second
> - Digital
>   - Uncompressed: >100 Megabits/sec
>   - Low-Compression: T-1 to DS-3
>   - High-Compression: Fractional T-1

- Analog video is an electrical waveform ranging frequency from 0 to 6 MHz. This is called baseband video. When modulated onto higher-frequency carriers, the signal can be broadcast over the air or over cable. When many channels are broadcast or received, the resulting signal is known as wideband.

- Baseband video can be transmitted over the air, over coaxial cable, over a pair of copper wires, over microwave radio, or over fiber-optic cable. When broadcast over the air, a wideband video signal can be multiplexed using frequency modulation. For example, FM multiplexing allows as many as 100 analog video signals to be transmitted over a single fiber-optic strand. Broadcast television, and some microwave wideband systems, use Amplitude Modulation (AM) to carry the signal.

- Digital video starts out as analog video, and is digitized and compressed into a digital channel. The greater the compression, the lower the image quality. T-1 speeds or greater can carry very good digital video for traffic surveillance. Lower speeds cause very noticeable degradation, either by reducing the colors, resolution, or framing rate, or a little of all three.

Video Transmission

Analog Video

- Analog video is in many ways a real bargain. The quality is very high, and the equipment required is very simple and inexpensive. For example, the typical equipment chain is: Camera-Coax-FM Multiplexor-Fiber-FM Demultiplexor-Switcher-Monitor. The multiplexors and switchers are simple and inexpensive, and are very commonly used in the broadcast and cable television industries.

> **Video Transmission**
> **Analog Video**
>
> - Advantages
>   - Simple–Low Equipment Diversity
>   - High-Quality–No visible degradation
>   - Cheaply transmitted over error prone media
> - Disadvantages
>   - Cannot usually share media with data

- Analog video can be readily communicated of a variety of media. Small errors in the media are not visible in analog video signal, and get passed through unnoticed without the overhead required to detect or correct them.

- Analog degrades gradually. Errors appear as snow. Only hug error rates cause so much snow that the image is unusable.

- Digital video degrades suddenly. When errors can no longer be corrected, the image usually freezes until the problem corrects itself.

Video Transmission
Digital Video

Video Transmission Digital Video
♦ Advantages – Can be circuit-switched – Uses telephone-style equipment – Shares media with data easily ♦ Disadvantages – Requires digital conversion/ compression – Complex—High Equipment Diversity – High quality images require expensive equipment

- Many new systems are being designed to share media between video and data. For example, a system that leases backbone space on fibers owned by the telephone company may have to prepare the video in a form that can share the fiber with other users. Moving video images digitally is usually the only alternative in such cases.

- But such systems are complex. The typical fully digital equipment chain from camera to monitor for digital video might be: Camera-Optical Driver-Multimode Fiber-Optical Receiver-Codec-Digital Multiplexor-SONET Frame-Single-Mode Fiber-SONET Frame-Digital Demultiplexor-Digital Network Switcher-Codec-Monitor. Portions of this chain are often performed in analog, especially the image switching from incoming lines to monitors in the control center. In such cases, the Codec, which returns the digital image to analog, comes before an analog video switcher.

- The single-mode fiber between the SONET frame, and possibly even the SONET frame itself, might be owned by a providing agency, such as the telephone company. The portion used by the system will in such cases be leased to the traffic system operator.

Communication System
Reliability

> **Communication System**
> **Reliability**
>
> - Communications Reliability:
>   - Media Reliability
>   - Equipment Reliability
> - System Reliability is a difference issue

- Communications reliability serves system reliability. System architectures can be designed to allow relatively low communications reliability. System reliability is the amount of time that motorists see the intended operation of the system. Communications reliability is percentage of time messages can be transmitted without errors, and is unrelated to equipment reliability, which is the percentage of time the equipment is working.

- Many systems that do not mandate real-time control messages can tolerate low communications reliability. Low reliability is something like 99.9%, which is about 45 minutes of downtime per month, and is typical of inexpensive wireless media. High reliability is more like 99.9998%, or a few seconds per year, which usually requires physical links such as copper wire or, even better, fiber. When critical control messages must be delivered in real time to avoid losses in system reliability, then the communications link must be able to provide high reliability. If the system can tolerate non-real-time delays in communications, then media of less reliability become possible.

Communication
Standards

- The traffic industry has had special needs in the past, and has often resorted to transpiration-industry-specific (and usually manufacturer-specific) communications protocols for talking to field devices. The current trend, however, is toward incorporation of computing and communications industry standards. These standards allow much greater flexibility in mixing and matching components in systems, and much greater use of inexpensive off-the-shelf software and equipment.

Communication
Standards

- Software—NTCIP
- Networking
- Communications

- The NTCIP provides standards for communications between central systems and roadside systems, with some work towards communications between control centers. The NTCIP uses computer-industry standards for networking, and depends on communications-industry standards for interfacing with the physical plant.

Communication
Media Characteristics

Communication
Media Characteristics
Media Characteristics

Media	Comm. Reliability	Capacity	Cost	Ease of Maintenance	Potential Problems
Analog Fiber	High	High	Moderate	Moderate	None
SONET Fiber	High	High	High	Moderate	None
Copper Pairs	High	Low	Moderate	High	None
Coaxial Cable	Moderate	Moderate	Moderate	Low	None
Data Radio	Low	Low	Low	Moderate	Spectrum Availability
Spread Spectrum	Low	Low	Low	Moderate	Limited Long-Term Viability
Microwave	Low	Low to High	Low to Moderate	Moderate	Spectrum Availability

NTCIP

NTCIP

What is the Problem?

- Currently, ITS projects use proprietary systems due to the lack of any standards. As such, individual projects are awarded to the low bid provider who is then not motivated to make his product compliant with any new standard.

What is the Problem?

- Agencies choose between competing proprietary systems.
- Low bid procurements can yield incompatibilities.

Why is it a Problem?

> **Why is it a Problem?**
>
> - Purchase of non-interchangeable equipment and systems
> - Acquisition of large spare parts inventories
> - Unsatisfactory documentation associated with multiple, unique implementations.

- Many agencies upgrade their systems in stages.
- In this case, there are two options for awarding the work for system upgrades after the original system in installed:

    1. The agency may choose to sole source the original provider. However, frequently this results in a bid price that is not as competitive as the original.

    2. The agency may go out to bid again; but, there is a strong possibility that a non-compatible system will be obtained. In addition, because there are multiple systems, spare parts inventories must be maintained for each system. Another problem is that these multiple systems require the maintenance and operation personnel to learn multiple system.

- Another alternative for some locals is for the agency to upgrade its entire system at once. While this produces a compatible system at a reasonable price, it can only be done infrequently and the devices must be maintained in the meantime. Because the product line and/or company may not be around in the future, agencies that have opted for this scenario have frequently found themselves purchasing very large inventories of spare parts to protect their investment.

Why is it a Problem? – cont.

Why is it a Problem? – cont.

- Incompatible deployments that are difficult to integrate into regional systems that provide seamless transportation services
- Increased costs associated with system expansion / integration
- Increased costs associated with maintenance and personnel training and recruiting

- When it is desired to integrate these smaller systems into larger ITS systems, agencies frequently discover that they are now faced with an expensive effort to develop a custom interface between two unique systems. Even if the individual systems are not entirely unique, the agency discovers that these two particular systems (versions, etc.) have never been integrated before and the entire development must be funded under a new project.

- This environment drastically increases the cost of expanding systems and integrating systems together. Further, with each of these unique development costs, comes a parallel unique training cost.

Why Solve It? – cont.

- In addition, the NTCIP will enhance interjurisdictional cooperation by resolving many of the technical and financial challenges facing such projects. It also allows the potential for jurisdictions to share communications infrastructure thereby reducing overall communication costs for ITS deployment. By lowering deployment costs, more extensive ITS systems can be deployed creating a larger market and lowering prices. Lower prices once again promote the extended deployment of ITS.

Why Solve The Problem

- Enhance inter-jurisdictional coordination and integration
- Share infrastructure – Interoperability
- Improve maintenance - Interchangeability
- Eases expansion
- Makes ITS feasible

- ITS becomes feasible, even in small jurisdictions where funding is less available, resulting in reduced accidents, reduced delays, better system performance, better air-quality, etc.

Interoperability

> **Interoperability**
>
> - Communications protocol is a set of rules for coding and transmitting messages between devices
> - Common language of communication
> - Interoperability permits different kind of devices to be interconnected on the same communications line

- One of the key concepts behind the NTCIP development is interoperability. This term is defined as allowing multiple devices of potentially different types (e.g., VMS and signal controllers) to communicate over the same infrastructure. To achieve interoperability, the messages exchanged while communicating with one device must not cause conflicts within the other device.

- The benefit of interoperability is that a single communications infrastructure system can be provided for the ITS. Without this feature, a VMS subsystem would need a separate infrastructure from the signals that would be separate from the ramp meters, etc. By combining the devices based on geographic location, the infrastructure can be deployed in a more cost efficient manner.

Interchangeability

- Another key benefit of the NTCIP is interchangeability. This term is defined as the ability to switch out a device by one manufacturer with a similar device from another manufacturer with minimal effects.

Interchangeability

- NTCIP also establishes the meanings of the messages
  - -- Provides a plug-and-play capability, interchangeability, that allows products from different manufacturers to be exchanged while providing consistent functionality

- Ideally, this could be done seamlessly. However, there are trade-offs in this benefit and the ability to let the standard to have flexibility for innovation and technology growth. The NTCIP standardizes all features which are frequently provided in devices while still allowing manufacturers to develop their own bells and whistles. This allows one device to be swapped out with another of the same type (e.g. a signal controller) and all key features will be available (although there may be some advanced features which are different).

OSI Reference Model

- NTCIP relies on acknowledged concepts for communications like the OSI (Open Systems Interconnection).

OSI Reference Model

OSI Layer	Services
Application	Defines procedures for file transfers, access methods and management of messages
Presentation	Encryption, text compression and reformatting
Session	Establishes, manages and terminates connections
Transport	Breaks longer messages into packets
Network	Routes packets of data from source to destination
Data Link	Ensures data integrity (e.g., error correction)
Physical	Defines the mechanical, electrical and procedural aspects of the physical link

- The OSI Reference Model is based on a concept developed by the International Standards Organization (ISO). The model is called the ISO OSI Reference Model because it deals with connecting systems that are "open" for communications with other systems.

- The OSI model consists of seven hierarchical layers. Each layer performs a related subset of the functions required to communicate with another system. Each layer relies on the next lower layer to perform other functions and to conceal the details of those functions. It in turn provides "services" to the next higher layer. These layers are defined in such a manner so that changes in one layer do not require changes in the other layers.

- This table identifies each layer and gives a brief description of the functions associated with each layer.

Communications Profiles

♦ Through the use of protocol identifiers, a high degree of flexibility can be achieved. Likewise, by providing consistent protocols where appropriate, the amount of code can be minimized.

Communications Profiles

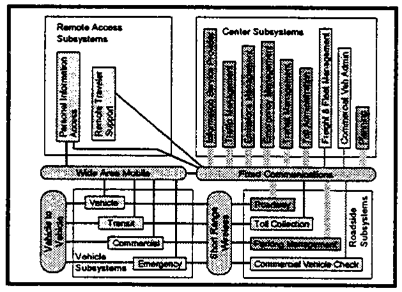
Direct Connection — *Message Routing* — *File Transfer* — *Center to Center*

	PROFILES			
OSI Layer	Class B	Class A	Class C	Class E
Application	STMF	STMF	Telnet FTP SNMP	Telnet FTP SNMP
Presentation	Null	Null	Null	Null
Session	Null	Null	Null	Null
Transport	Null	UDP	TCP	TCP
Network	Null	IP	IP	IP
Data Link	PMPP	PMPP	PMPP	PPP
Physical	EIA 232E FSK	EIA 232E FSK	EIA 232E FSK	EIA 232E

National Architecture Compatibility

- The NTCIP will eventually address virtually all fixed point communication links within the ITS Architecture. However, the initial focus of the NTCIP is on the center-to-roadside link. Efforts are now beginning to define the standards for center-to-center links but these are still in their early stages.

National Architecture Compatibility



Architectural Diversity

- The NTCIP effort has also recognized that there are a wide variety of installed and planned architectures within ITS. The development effort has explicitly focused on developing a standard that can support most any architecture design foreseeable. A few samples of these will follow.

Architectural Diversity

Different systems need
different architectures

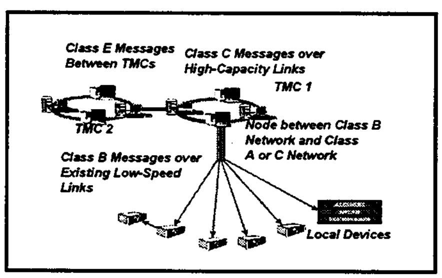
Traditional Centralized Architecture

- This figure depicts a typical two level central system. Control decisions are made at central (TMC1) and communicated to the devices that are directly connected on dedicated lines or multi-drop lines. Central is also able to monitor field conditions over the same link. Communications with each device typically occurs on a second-by-second basis over low speed (e.g., 1200 BPS) communication lines. Finally, the devices may be homogeneous or heterogeneous (e.g., as depicted here with both signals and a VMS)

Traditional Centralized Architecture

- Circuit switched
- Low speed to field
- Class B from Center to field
- Allows reasonable polling rate
- Class A or higher within Center

- TMC 2 is able to exchange information with TMC 1 regarding device information.

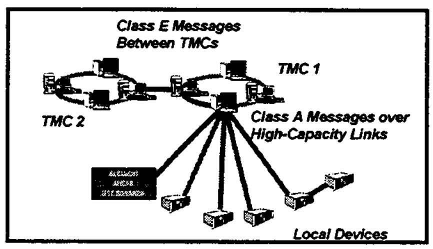


Advanced Centralized Architecture

Advanced Centralized Architecture

- Circuit switched
- High-speed to field
- Class A from Center to field
- High-speed allows more powerful protocal

- More advanced systems may make use of higher speed communications which route messages as needed or exchange larger volumes of data. In this scenario TMC 2 could communicate directly with the remote devices by routing messages through central. The routing feature requires greater bandwidth and thus is difficult to implement on lower speed systems.

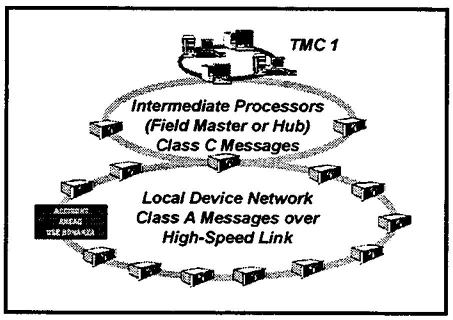


Distributed System with High-Speed Infrastructure

- Another architecture that may be deployed is metropolitan area networks. In this environment, field devices communicate in a peer-to-peer fashion within their subnet and then are able to exchange information with central or other subnets through a router.

Distributed System with High-Speed Infrastructure

- Packet switched
- High-speed to field
- Class A allows routing with global addresses
- Opens door to peer-to-peer

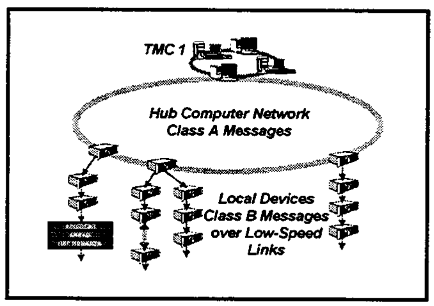


Distributed System with Low-Speed Infrastructure

- Another architecture is to have only the routers on a peer-to-peer network and to have the field devices daisy chained off of the router. This may be an interim solution in going to a more advanced design or a simple way to tie in systems.

Distributed System with Low-Speed Infrastructure

- Packet witched
- Physical addressing from hub to local
- Logical addressing from center to hub

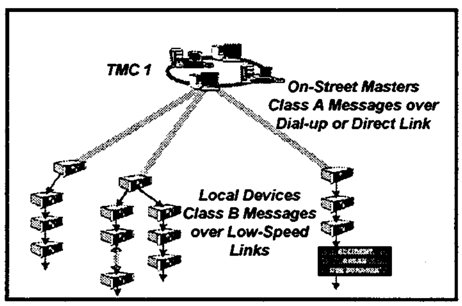


Traditional Closed-Loop System

- A more traditional design is to have central communicate with a field hub such as an on-street master, and then the master communicates with the local controller.
- In short, the NTCIP is flexible enough to support any of these environments and has been developed in a fashion that should enable it to support future designs as well.

Traditional Closed-Loop System

- Packet switched
- Uses Class D for dial-up link



Included Devices

- As mentioned before, the initial NTCIP effort focuses on the development of the center-to-roadside communications link. Active efforts are underway to develop standards for these devices.

Included Devices

- Signal Controllers
- Dynamic Message Signs
- Environmental Sensor Stations
- Cameral Control
- Ramp Meters
- Highway Advisory Radio

Other Devices

- Efforts for these devices are forming.

Other Devices

- Transit Devices
- CVO Devices (e.g., WIM)
- Advanced Detection Devices

Object Definitions

- TS 3.4 defines those data elements which are generic to many different device types. For example, many devices will have to support data elements for things such as time-of-day and manufacturer name.

Object Definitions

- TS 3.4 – Global Objects
  -- A dictionary of terms used in many different letters
- TS 3.5 – ASC Objects
  -- A dictionary of terms for signal controllers

- TS 3.5 defines those data elements which are unique to actuated traffic signal controllers. These include all of the phase and coordination parameters as well as status and control variables.
- These documents are analogous to a dictionary for language. They make precise definitions of what each data element is.

Status of Other Object Standards

- Additional standards are being developed to define those data elements which are unique to the following:
  1. Dynamic Message Signs (DMS), these include variable message signs, changeable message signs, and blank-out signs.
  2. Environmental Sensor stations, including both Road/Weather Sensors and Air Quality Sensors
  3. Ramp Meters
  4. Camera Controllers
  5. and Highway Advisory Radio

Status of Other Standards

- Dynamic Message Signs – Q1 1997
- Environmental Sensors – Q2 1997
- Ramp Meters – Q3 1997
- Cameral Control – Q3 1997
- Highway Advisory Radio – Q3 1997

Procurement Specifications

> **Procurement Specifications**
>
> - Needs to Specify All Selected Options
> - Should minimize restrictions
> - Can refer to NTCIP Guide for sample wording
> - Specification can refer to NTCIP guide tables to facilitate reading

- Thus, the procurement specifications should specify all of the options that the design engineer requires, however, extra conditions should be minimized to allow manufacturers to have the maximum flexibility in designing their product with innovative features.

- To aid the engineer in writing these specifications, the NTCIP Joint Standards Committee has developed a sample procurement specification in the NTCIP Guide. This sample provides an excellent start for writing specifications, but the specific needs of the project must still be considered. To the extent possible, the engineer should match the range designations in the Guide to minimize work by the manufacturer in ensuring his device will meet procurement specifications.

- It should be noted that as of December 1996, the Guide Procurement Specification has not been used in a real procurement, but this sample provides a starting point.

Compliance Testing

- Once the system has been procured, the agency must test the system to ensure that the devices meet the specification. A valuable tool for the agencies is currently under development by the FHWA, the NTCIP Exerciser. This software package will allow the user to send test messages to the device to ensure that it responds appropriately. If there is any inconsistency reported, the issue can be brought to the attention of the NTCIP Joint Standards Committee for resolution. It should be realized that the Exerciser is a new product as well and may itself be in error from the standards. Thus, it is the NTCIP Joint Committee responsibility to ensure that any discrepancies are resolved which may entail a change to the Exerciser software.

Compliance Testing

- NTCIP Exerciser under development
- Will allow for testing of devices
- Comments are requested by the Joint NTCIP Steering Committee

Where to get more information

- More information is available through these sources.

Where to get more information

- Conferences
- ITE Journal Articles
  - -- April 1996
  - -- January 1996
  - -- December 1995 Special Issue
- World Wide Web Site
  - -- http://www.fhwatml.com/ntcip
- NTCIP Guide
- Communication Books

Traffic Signal Control Systems
Overview

- Traffic Signal Control Systems provide coordinated control of individual traffic signals to achieve network-wide traffic operations objectives.

Traffic Signal Control Systems
Overview

- Traffic Signals
- Communications Network
- Central Computer

- The system consists of intersection traffic signals, a communications network to tie them together, and a central computer or network of computers to manage the system.

- The basic purpose of a system is to provide access between engineers and field hardware to make favorable signal timings for the motoring public easier to implement.

Surface Street Control

Techniques / Strategies

- Surface street control systems provide the majority of traffic signal system applications.
- The systems are solely intended to provide control of networks of signal-controlled streets.

Surface Street Control
Techniques / Strategies

- Isolated Intersections
- Interconnected Signals
- Special Controls

Surface Street Control
Isolated Intersections

Surface Street Control
Isolated Intersections

- Traffic Signals
- Warrants
- Operation

- Isolated traffic signals are the basic building blocks of signal systems.

- The decision to install a traffic signal depends on the conditions at the intersection meeting one of a series of warranting conditions, as defined in the MUTCD.

- The installation of isolated pretimed intersections has become rare. Since most signals in isolated circumstances control highly variable traffic, actuated controls works better.

Surface Street Control

Interconnected Signals

Surface Street Control
Interconnected Signals

- Distributed Systems
- Central Control Systems

- Traffic signal operation is tied together into a coordinated system when traffic signals are close enough together that traffic remains in recognizable platoons from one intersection to the next.

- In distributed systems, the intersection controller is responsible for control decisions at the intersections.

- In centralized systems, a central computer makes control decisions and diverts the actions on individual controllers.

Interconnected Signals
Distributed Systems

Interconnected Signals
Distributed Systems

- Powerful Controllers
- Robust
- Expandable
- Inexpensive

- Distributed systems rely on powerful local intersection controllers that must have all the features desired for signal control at the intersection.

- Distributed systems do not transmit mandatory real-time control commands over the communications network. Thus, coordination can be maintained even during communications and central computer down time.

- Distributed systems can be easily expanded to sufficiently incorporate a new intersection simply by adding communications infrastructure.

- Inexpensive, low-reliability communication alternatives can be used with distributing systems, thus reducing the overall cost.

- Distributed systems do not need real-time surveillance of intersections for control purposes.

Interconnected Signals
Central Control Systems

> **Interconnected Signals**
> **Central Control Systems**
>
> - Require reliable communication
> - Expandability limited by computer
> - Expensive
> - Allows global real-time adaptive control

- Central systems depend on reliable communications networks. Because real-time control commands are being transmitted from the central computer to the local intersection, any interruption in the communications network will force the local controller to operate without real-time control. Thus, central systems also depend on reliable central computers.

- Central systems are not easily expandable since increasing the size of the network requires a significant investment in central computer and software upgrades.

- Communications networks in central systems typically consume a significant cost of a system, increasing the overall cost of the system.

- Central systems provide excellent surveillance response time.

Surface Street Control
Special Controls

Surface Street Control
Special Controls

- Preemption
- Priority Systems

- Preemption systems respond to special conditions, by preempting the operation of the controller and taking over the operation for the duration of the special condition.
- Priority systems give special consideration to one class of vehicles without completely preempting the normal operation of the signal.
- The special conditions that call for preemption and priority are railroad, emergency vehicle and transit vehicle needs.

Surface Street Controls
Technologies

Surface Street Controls
Technologies

- UTCS
- Closed Loop Systems
- Traffic Adaptive Signal Control
- Traffic Controllers

- Virtually all mainframe traffic control systems in operation in the US are based on the Urban Traffic Control Systems (UTCS) developed by FHWA.

- Closed loop systems provide two-way communication between the local controllers and the on-street masters and vice versa.

- Traffic adaptive signal controls adjust signal-timing parameters based on traffic conditions and detector data.

- Traffic controller technology, the basis of surface street control, is expanding to handle ITS functionality.

Surface Street Controls
Technologies (cont'd)

Surface Street Controls
Technologies (cont'd)

- Arterial Highway Advisory Radio
- Arterial Video Surveillance
- Arterial Video Image Processing
- Arterial Detection

- HAR can be placed at key locations along major arterials displaying similar real-time information as with DMS.
- An arterial CCTV system can provide surveillance of arterial sections, intersections, visual confirmations of incidents, and information on the types of assistance required.
- Arterial video image processing are detection systems that use microprocessor hardware and software to extract real-time traffic flow data through an analysis of video images collected by a series of cameras.
- Accuracy of detection systems as well as reliability becomes very important issues when dealing with arterial systems and intersection control.

Technologies
UTCS

- The 1st generation control uses prestored traffic signal timing plans developed offline and based on historical traffic patterns.

Technologies
UTCS

- 1st Generation Traffic-Responsive
- 1.5 Gen. Offline Optimization
- 2nd Generation Online Optimization
- 3rd Generation Adaptive Control

- The 1.5 generation control is an online timing plan generator with automated loading of the generated plans into the traffic control system.
- The 2nd generation control was developed as an online model that computes and implements signal timing plans in real-time based on surveillance data gathered from vehicle detectors and predicted traffic volumes.
- The 3rd generation control allows signal timing parameters to change continuously in response to real-time measurements of traffic variables.

Technologies
Closed Loop Systems

Technologies
Closed Loop Systems

- Time-of-day
- Manual
- Traffic Responsive

- With the time-of-day mode, the controller selects and implements a pre-specified signal-timing plan based on time-of-day, day-of-week, and/or time-of-year.
- Under the manual mode, the operator specifies the desired timing plan.
- In the traffic responsive mode, the computer automatically selects a timing plan, from a library of plans, to accommodate the current traffic conditions.
- The closed loop system consists of system detectors, local control equipment, controller-master communications, on-street master, master-central communications, and a central computer.

Technologies
Traffic Adaptive Signal Control

Technologies
Traffic Adaptive Signal Control

- SCOOT
- SCATS
- RT-TRACS

- SCOOT (Split, Cycle, and Offset Optimization Technique) uses detector occupancy and gap information to optimize timing parameters.

- SCOOT is a centralized algorithm based on once-per-second mandatory communication with the local intersection controller.

- RT-TRACS (Real-Time Traffic Adaptive Control System) is a project that will develop and field evaluate a real-time, traffic adaptive signal control system suitable for use in the ITS environment.

- RT-TRACS will be designed to control a maximum of 5,000 intersections, in order to accommodate universal control in large urban area.

Technologies
Traffic Controllers

- Traffic controller technology is divided into two camps represented by two different specifications strategies and represents nearly all the installed infrastructure of current signal systems (NEMA and Model 170).

Technologies
Traffic Controllers

- NEMA TS-1
- Model 170
- NEMA TS-2
- Model 2070

- NEMA TS-2 and Model 2070 controllers have emerged to provide the advanced functionality needed by ITS technologies.

Technologies
Arterial Highway Advisory Radio

- The information content of a HAR is to provide real-time traffic information at key locations along major arterials.
- Live messages and prerecorded message can also be used for surface street applications.

Technologies
Arterial Highway Advisory Radio

The primary use of HAR is to provide real-time traffic information at key locations along major arterials.

Technologies
Arterial Video Surveillance

- Since street lighting is available on many urban arterials, color cameras are well suited for arterial surveillance.
- Cameras can be used to observe and verify unused vehicle capacity on surface streets before implementing freeway diversion strategies.
- Cameras can be used to evaluate signal timings for arterials and to verify signal timing coordination.

Technologies
Arterial Video Surveillance

- P/T/Z Capabilities
- Color vs. Black and White
- Capacity Observations
- Signal Timing Evaluations

Technologies
Arterial Video Image Processing

- Several cameras can be mounted in such a way that all approaches to an intersection can be observed without pan / tilt/ zoom.
- Approach and Traffic counting, intersection surveillance and queue length detection, system detection.

Technologies
Arterial Video Image Processing

- Intersection Detection
- Intersection Traffic Counting
- Intersection Surveillance
- Queue Length Detection

Technologies
Arterial Detection

- There is less room for error when considering intersection detection and control as opposed to the use of detectors for freeway management and control.
- The output type for arterial detection is important as detection failure could result in absence of calls.
- The location of detectors in traffic signal control is different than freeway systems; thus, care must be taken in selecting link, lateral and longitudinal detector placement.

Technologies
Arterial Detection

Freeway Detection vs. Arterial Detection

Freeway Incident Management Systems

Overview

- Freeway incident management is the coordinated and pre-planned approach used to restore freeway traffic to normal operation as quickly as possible after an incident has occurred.

Freeway Incident Management Systems

Overview

- Non-recurring
- Unpredictable
- Random

- Freeway incidents include traffic accidents, vehicle breakdowns, spilled loads, adverse weather conditions and rubbernecking.

Freeway Incident Management Systems

Techniques/Strategies

- Freeway incident management strategies may be categorized into four (4) basic techniques.

Freeway Incident Management Systems

- Detection
- Verification
- Response and Clearance
- Driver Information

Freeway Incident Management Systems

Detection

- Incident detection is responsible for identifying possible events and reporting them to system users for further disposition.
- The system will accept processed detector data and evaluate the data based on all algorithms chosen and generate log entries for events and place them in the system.

Freeway Incident Management Systems
Detection

- Electronic Surveillance
- CCTV
- Aerial Surveillance
- Motorist Call Systems
- Cellular Telephone
- Citizen Band Radio
- Police and Service Patrol

Freeway Incident Management Systems
Verification

- Since electronic detectors cannot determine the nature of incidents, some form of verification or confirmation is required to determine the necessary response.

Freeway Incident Management Systems
Verification

- CCTV
- Aerial Surveillance
- Call Boxes
- Patrol Vehicles
- Citizen-Band Radio
- Cellular Telephone

Freeway Incident Management Systems

Response and Clearance

Freeway Incident Management Systems

Response and Clearance

- Participating Agencies and Partners
- Resources and Responsibilities
- Transportation Management Center
- Inter-Agency Communication

- The key to minimizing congestion or adverse impacts of an incident is the timely and safe removal of the incident from the travel way and restoration of the freeway to its full capacity.

- It is very important to identify the resources required to respond and clear the incident, and responsibilities of each agency.

- All communications to and from the participating agencies and partners occur at the TMC.

- Inter-agency communication links include phone, dedicated or shared radio, pagers, Internet and Intranet. An incident management coordinator from each agency should be notified during an incident.

- Emergency response techniques and strategies are needed to get emergency vehicles to incident site surrounded by queued vehicles and to maintain order to emergency vehicles on the scene.

Freeway Incident Management Systems

Response and Clearance (cont'd)

> **Freeway Incident Management Systems**
> **Response and Clearance (cont'd)**
>
> - Incident Management Procedures
>   - Traffic management procedures
>   - Securing the scene
>   - On-site traffic control
>   - Accident investigation sites
>   - Vehicle removal and towing
> - Media

- Establishing incident management and operational procedure is vital to the response and the clearing of an incident.

- The magnitude of traffic management and control strategies used in a response plan is based on key information such as the period, severity and anticipated duration of the incident, as well as emergency medical and rescue needs.

- Securing the scene involves managing the scene and providing leadership in the activities that take place.

- On-site traffic control is needed to direct the orderly movement of traffic past the incident site or to incorporate route diversion techniques.

- Accident investigation sites are special designated sites, off the freeway, where police can perform an investigation on the incident, and drivers can exchange important information.

- Fast vehicle removal legislation policies have been enacted to reduce the impact of incidents and increase motorist safety.

Response and Clearance
Communication Links

- Communication links are needed to convey information quickly and accurately include the use of commercial radio, radio (800 MHz), single emergency frequency and cellular phones.

Response and Clearance
Communication Links

- Field-to-Field
- Field-to-Dispatch
- Dispatch-to-Dispatch

- Field-to-field communication is communication among personnel at the scene.

- Field-to-dispatch communication is communication between personnel at the scene of an incident and personnel at their agency's dispatch or operations center.

- Dispatch-to-dispatch communication is communication between dispatch or operations center of responding agencies.

Freeway Incident Management Systems

Driver Information

- An advance warning of an incident to the motorist will encourage the motorist to take alternative routes.

Freeway Incident Management Systems
Driver Information

Information should be:
- Accurate
- Timely

and include
- The nature of incident
- Extent of any delays

Driver Information
Technologies

Driver Information
Technologies

- Media
- Highway Advisory Radio
- Dynamic Message Signs
- In-vehicle Displays

- Many media outlets either provide their own coverage of traffic or solicit traffic information from private traffic reporting firms and / or the TMC.

- Although primarily broadcast at 530 or 1610 kHz, AM bands, FCC will allow the use other available frequencies for HAR.

- DMS can be at fixed locations or portable.

- In-vehicle displays can provide real-time information in voice and video format.

Driver Information
Technologies (cont'd)

Driver Information
Technologies (cont'd)

- Video Text
- Telephone Dial-in
- Information Kiosks
- Internet

- Video text is the use of the vertical blanking interval in television broadcasts to transmit information.
- Some areas have telephone numbers for traffic information pre-packaged to be route or trip specific.
- Information kiosks are automated traffic units usually displayed on video monitors and located in major transportation, employment, and retail centers.
- Internet becoming the fast expanding way to transmit real-time traffic and road conditions.

Surface Arterial Incident Management Systems

Issues

Surface Arterial Incident Management Systems

Issues

- Multiple Access
- Interrupted Flow
- Geometric Constraints
- Control Measures
- Operating Conditions
- Detector Configurations

- Not much work has been performed in the research, development and implementation of surface street incident management systems.
- Measures of traffic flow such as volume, occupancy, and speed used to detect incidents on freeways experiencing interruptions and fluctuations, don't readily apply to incidents on surface streets.
- Several characteristics of surface streets make incident detection different than freeway incident detection.

Electronic Toll Collection System

Overview

- ETC, a major component of Electronic Toll and Traffic Management, is a combination of techniques and technologies that allows vehicles to pass through a toll facility without requiring any action by the driver.

Electronic Toll Collection System
Overview

Components:
- In-lane/Roadway components
- Facility management
- Customer Service Center

Electronic Toll Collection System
In-lane/Roadway Components

- AVI allows for the identification of the vehicles and ownership for the purposes of charging the toll to the customer and also provide a mechanism for data collection for various traffic management strategies.

Electronic Toll Collection System
In-lane/Roadway Components

- Automatic Vehicle Identification (AVI)
- Automatic Vehicle Classification (AVC)
- Video Enforcement Systems (VES)

- AVC is used to determine the configuration of the vehicle for the purpose of charging the appropriate toll to the customer.
- VES, also called violation enforcement systems, allows the toll equipment to capture information on vehicles that have not paid the proper toll.
- All in-lane/roadway components are in communication with and controlled by a computer called "lane controller" which takes input from the various components and passes it to plaza host computer.

Electronic Toll Collection System

AVI Technologies

Electronic Toll Collection System
AVI Technologies

- Inductive loop systems
- Optical systems
- Active RF/Microwave systems
- Passive RF/Microwave systems
- Surface Acoustical Wave (SAW)

- Inductive loop systems use loop antennas to transmit data to and from the vehicle tag. It is the earliest of AVI technologies.

- Optical systems use either a system that reads license plates directly and identifies the vehicle from a database, or a system where the vehicle tag is simply a bar code read by a laser scanner to retrieve vehicle classification.

- Active radio frequency (RF) systems have a high data rates that allow multiple transmissions, which are commonly known as "handshakes." Active tags generate their own microwave signal with the use of a power source.

- Passive RF communication, sometimes called the "backscatter" method, uses tags that reflect the microwave signal that it receives.

- SAW uses a low-power radio frequency signal and a lithium crystal to transmit data by means of an acoustical wave.

Electronic Toll Collection System

AVI Technologies

Electronic Toll Collection System
AVI Technologies
Electronic Tags/Transponders
- RF Tags
- RF Smart Tags
- Smart Cards with RF Transponders

- 3-types of RF tags
  - Type I – information stored in the tag is fixed (read only) and cannot be changed and the tag does not have any processing capabilities.
  - Type II – contains an updateable (read/write) area on which the antenna/reader may encode information
  - Type III – contains communication ports to allow the tag to communicate with other devices in the vehicle.
- RF Smart Tags contain microprocessors which maintains account balance information which is updated each time the smart tag is used. Some portions of the tag information are fixed (vehicle and customer data) while others are updated (balance information). Not used extensively in the US.
- Smart cards with RF transponders use a type III RF tag located in the vehicle to interfaces to the smart card and allows the smart card to communicate with the in-lane antenna/reader.

Electronic Toll Collection System
AVC Technologies

Electronic Toll Collection System
AVC Technologies

- Inductive loops
- Treadles
- Light curtains
- Scanning devices
- Video image processing

- Inductive loops detect vehicle presence by sensing the metallic mass of the vehicle.

- treadles are pressure-sensitive devices installed in the road bed to determine the number of axles, number of wheels, and direction of vehicle crossing the treadle.

- Light curtains emit multiple horizontal light beams to measure vehicle presence and profile.

- Scanning devices generate radiation at various frequencies to detect vehicle presence and profile.

- VIP uses video cameras to scan traffic and built-in software to determine vehicle profile (length, height, and width).

Electronic Toll Collection System
VES Technologies

Electronic Toll Collection System
VES Technologies

- Photographs
- Videotape recording (VTR/VCR)
- Digital Imaging
- License Plate Recognition (LPR)

- Photographs were originally taken of toll evading vehicles. Because of the intensive amount of work involved in extracting vehicle plate information from the photographs, this approach is no longer deemed acceptable.

- Videotape recording devices are used to capture images of vehicles going through the lane, where the tape could be replayed to review images and extract license plate information. Requires a video camera and a dedicated videotape recorder in each lane.

- Digital systems feature the ability to digitize images, store them electronically, and transmit them to remote locations. They can be enhanced through the use of license plate recognition systems

Electronic Toll Collection System

Facility Management and Customer Service Center

- The Center communicates and manages the operation of various ETC components mentioned earlier.
- It also consolidates the database as well as equipment requirements for the system.

Electronic Toll Collection System

Facility Management and Customer Service Center

- The Center manages the accounts, enrolls customers, issues tags, processes violators, handles all inquires and provides for an exchange of information and data with other ITS components in the region

Transit Management System
Components

- Fleet Management – focuses directly on strategies and technologies that can be applied to improve vehicle and fleet planning, scheduling and operations.

Transit Management System
Components

- Fleet Management
- Traveler Information
- Electronic Fare Payment
- Transportation Demand Management

- Traveler Information – provides the user with information regarding various modes of the transportation system.
- Electronic Fare Payment – Process of automated fare collection and subsequent record keeping and final transfers.
- Transportation Demand Management – A process which employs series of strategies to manage the demand on the transportation infrastructure.

Fleet Management
Strategies

- Primary Benefit – to improve efficiency and safety of the vehicles which results in a reliable system that could attract new ridership and help the operation become more cost effective.

Fleet Management
Strategies

- Planning
- Scheduling
- Operations

Fleet Management
Techniques

- System wide communication is necessary to allow transfer of data and voice between the field and the operation center.
- GIS assists to spatially manage the system.
- The AVL defines vehicle locating techniques.
- Transit Operations Center and Software provide the tools necessary to operate and manage the fleet efficiently and effectively.

Fleet Management
Components

- Communication System
- Geographic Information System
- Automatic Vehicle Location
- Transit Operations Software/Center

Communication Systems
Technologies

Communication Systems
Technologies

- FCC Licensed Frequeny
- Shared Spectrum
- FM Sub-Carriers
- Wireless Data Services

- Licensed frequencies to cover large areas using FM, AM or SW radio frequencies to transmit voices and data. May require significant effort in terms of application process and legal issues.

- Shared Spectrum Systems – Sharing a spectrum with other public agencies using features of digital trunking. Ex. 800 and 900 MHz systems.

- FM Sub-Carriers – Radio Data Systems (RDS). Use the unused portion of a FM radio frequency to pack voice and data information for transmission.

- Wireless Data Services – Commercial data services such as ARDIS or Cellular Digital Packet Data (CDPD).

Geographic Information System
Overview

> **Geographic Information System**
>
> GIS is a computer-based system that combines hardware, software, and procedures to capture, manage, manipulate, analyze and display spatially referenced data.

- Applications include service and facility planning, routing operations, market development, customer information and service, and system analysis.
- Service and facility planning for bus routes, bus assignments, scheduling, ridership, parking lots, facilities, shelter locations, running times, accident analysis and customer complaints.
- Operations using street and route maps, service performance monitoring, emergency call location identification and vandalism location and history.
- Market development using maps and data that identify land uses, employment sites, demographics and travel patterns.
- Customer information and service through bus route maps, trip planning and route selections, on-time performance data, and customer data.
- Transportation service analyses such as service performance statistics, origin and destination of ridesharing applicants, ADA adherence and HOV monitoring.

Automatic Vehicle Location (AVL)
Overview

- Using various technologies, AVL are used to identify location of the vehicle.

- AVL uses in transit operation have increased with the introduction of ISTEA and the Clean Air Act.

Automatic Vehicle Location (AVL)
Overview

Computer-based vehicle tracking system

- Primary benefits of AVL are increased operating efficiency, increased service reliability, and improved safety.

Automatic Vehicle Location (AVL)

Additional Benefits

- Improved detection of mechanical problems.
- Input to passenger information systems.
- Input to preferential traffic signal activators.
- The additional benefits are realized through the incorporation of the AVL system into an overall Transit Management System which allows for exchange of information and data between its components.

Automatic Vehicle Location (AVL)
Additional Benefits

- Improved detection
- Input to APTS
- Preemption
- Improved database

- AVL requires a transmission mechanism (communication systems) between the vehicle and the center. If this mechanism is in place, then the other APTS components could use the same system to exchange data and information.
- The constraint is simply the selected communication system capacity and capability of the hardware and software that supports the TMS.

Traveler Information System
Techniques

- Pre-Trip - plan the mode of travel, best route, and/or time of travel.
- En-Route - provide user with real-time status of the transportation services and network to allow for informed decisions.

Traveler Information System
Techniques

- Pre-Trip
- En-Route

Traveler information
Systems may provide the following type of information.

- General information may include information about available transportation services in the region.
- Schedule information can provide the user with a time table/itinerary for a given trip.
- Operation information can provide the user with real-time status of the transportation systems and services.

Advanced Public Transportation Systems (APTS)

Transit Operation Software

- Transit management software have been developed to allow the integration of a GIS based system with other APTS components such as AVL, computer-aided dispatching, and service and performance monitoring.

Advanced Public Transportation Systems (APTS)
Transit Operation Software

Regional Multimodal Traveler Information Systems

Overview

> **Regional Multimodal Traveler Information Systems**
> **Overview**
>
> - Centralized source of road and transit information
> - Focal point for information collection and dissemination

- There is a need for a centralized source of real-time roadway and transit information to provide a comprehensive and integrated view of the road and traffic conditions throughout the metropolitan area.
- The total regional transportation network covers all modes (road and transit), all types (freeways and arteries) and all areas (adjacent cities and counties).
- Requires interconnection of traffic management centers and exchange of real-time data.
- Real-time roadway and transit information is packaged in a variety of formats and distributed through different means by the Regional Center.
- The Regional Center provides/supports a level of data integration to clearly reflect the status of the road network and transit information.

Case Studies

Atlanta Traveler Information Showcase

> **Case Studies**
> **Atlanta Traveler Information Showcase**
>
> - Personal Communication Devices
> - In-Vehicle Navigation Devices
> - On-Line Computer Information Services
> - Interactive television
> - Cable TV
> - Information Kiosks

- The Atlanta TIS provides timely information on multimodal travel options through a variety of platforms.

- Personal communication devices include hand-held computers and pagers to access real-time traffic information, electronic yellow pages and other services.

- Real-time traffic information is delivered to the in-vehicle device via FM subcarrier broadcast and is updated every 90 seconds, depending on the volume of data being transmitted.

- An Internet World Wide Web site provides information on route planning support, yellow pages information services, and transit itinerary planning services.

- An interactive television system in area hotels provides real-time traffic information on incidents, highway speeds, public transportation and tourist information.

- Traffic Information that is broadcast over cable systems include area maps with icons showing incident locations and color coded segments indicating current traffic speeds, live surveillance video feeds and traffic advisory bulletin boards.

- Information kiosks are installed in transit stations, hotels, visitor centers, hospitals, airports, office buildings, rest areas, and shopping centers offer real-time traffic, transit, weather, and tourist information.

Case Studies

Other Traveler Information Systems

Case Studies
Other Traveler Information Systems

- Washington Metropolitan Traveler Information Service
- Boston SmarTraveler System
- ARTIMIS
- ATIS Grant
- HEDAS
- TravInfo
- TransCal

- The WMTIS will implement a regional multimodal traveler information system that will utilize a fully staffed traveler information center, a data gathering system, the Smart Traveler audiotext system to disseminate information, and the use of a public agency information exchange network.

- The Boston SmarTraveler System includes a fully staffed Traffic Operations Center, and numerous stationary and rotating video cameras, which provide real-time information that is processed through the SmartRoutes proprietary traffic management software.

- The Advanced Regional Traffic Interactive Management Information System is a cooperative project in the greater Cincinnati and Northern Kentucky area that uses state-of-the-art technology to help local drivers avoid traffic tie-ups, facilitate smoother traffic flow through the area, and help reduce traffic accidents.

- The ATIS grant is a multi-agency partnership to apply the ATIS technology to the I-29, I-90, and I-94 corridors in North and South Dakota with the goal of providing precise weather information for integration into an ATIS support system to produce safer highway operations.

- HEDAS is an operational test in Iowa and Colorado that will disseminate important traveler information in difficult-to-reach, remote rural areas using a subcarrier on an AM broadcast station.

- The TravInfo project will develop and implement a multi-modal transportation information center to integrate transportation information from a wide variety of sources and make it available to the general public, public agencies and commercial vendors in the San Francisco Bay Area.

- The TransCal project is an inter-regional traveler information system that integrates and delivers road, traffic, transit, weather and traveler service information across the entire region to fixed and en-route travelers via various user devices. The service operates along I-80/US 50 corridor between San Francisco, California and Lake Tahoe/Reno, Nevada.

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Case Studies
Other Traveler Information Systems (cont'd)

Case Studies Other Traveler Information Systems (cont'd)
♦ Houston Smart Commuter ♦ Digital DJ ♦ Los Angeles Smart Traveler ♦ "Showcase" Intermodal Transportation Management and Information System (ITIMS) ♦ Seattle Wide Area Information for Travelers (SWIFT) ♦ Busview ♦ Riderlink

- The aim of the Houston Smart Commuter project is to increase bus, vanpool, and carpool use by providing real-time traffic and transit information to travelers at home and work.

- Digital DJ project will start broadcasting traffic data and other information in the San Francisco area over high speed FM subcarrier technologies.

- The LAST system is a traveler advisory telephone system deployed throughout southern California (1-800-COMMUTE).

- The ITMIS project will deploy technology to improve traffic and transit operations and provide information to transportation managers, travelers, and others in the Orange County region to enhance decisions on transportation management, route selection and mode choice.

- The SWIFT operational test will provide ATIS capability using a high speed data (FM subcarrier radio) system communicating to receiver devices capable of receiving FM subcarrier communications. Receiver devices being tested are Delco radio receivers, IBM portable computers and Seiko Message Watch.

- The Busview project takes existing Metro bus AVL data and combines it with a GIS map database to deliver real-time bus location information over the worldwide-web in the Seattle area.

- The Riderlink project will provide a comprehensive collection of transit, carpool, and vanpool information over the Internet.

Case Studies
Other Traveler Information Systems (cont'd)

- The Information Exchange Network is a wide-area network of interconnected transportation management centers sharing real-time traffic information and transit, airport, rail, and motor carrier information.

Case Studies
Other Traveler Information System (cont'd)

- Information Exchange Network
- Minnesota Guidestar-Trilogy
- Minnesota Guidestar-Genesis
- Driver Hogback Multimodal Transfer Center
- Driver Information Radio Experimenting with Communication Technology (DIRECT)
- Traffic Assist

- The Trilogy project will provide traveler information through different communications techniques: Radio Broadcast Data System-Traffic Message Channel (RBDS-TMC) and a high-speed FM subcarrier. End users will be provided with area and route-specific advisors on the highways operating conditions in the Twin Cities metropolitan area.

- Genesis is an advanced traveler information system that uses personal communication devices to distribute real-time transit and traffic information for route and mode choice decisions.

- The DHMTC will provide real-time traffic information by means of kiosks to Denver Travelers.

- Direct is an operational field test that deploys and evaluates several alternative low-cost methods of communicating advisory information to motorists.

- Traffic Assist is a private company providing real-time traffic information and routing information to users via telephones, pagers, and PDAs.

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